8.—Upper Eocene Planktonic Foraminiferida from Albany, Western Australia

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Abstract

A sample of 2500 planktonic foraminifera from the Nanarup Limestone Member of the Plantagenet Group at Nanarup, near Albany, on the south coast of Western Australia has yielded 22 taxa (form, species, etc.) of which *Globanomalina micra* (Cole), *Globigerina ampliapertura* form *ampliapertura* Bolli and *Globigerapsis index* (Finlay) are dominant, the latter making up 60% of the planktonic fauna. *G. index* is discussed in some detail, and statistical analysis of 436 specimens indicates that such generic names as *Globigerinita, Catapsydrax* and *Globigerinoides* must be used on a more restricted basis than at present, and that *Globigerinatheka, Globigerinatella, Globigerinoita* and *Inordinatosphaera* must be rejected. *Globigerina ciperoensis* form *basaapertura* and *G. jenkinsi* are described as new. The warm water fauna is Upper Eocene in age.

Introduction

The Plantagenet Group is mentioned (as the Plantagenet Beds) in numerous publications, most of which deal with mineral resources of Precambrian inliers, water or petroleum possibilities in the sediments, and the general geology of small areas within the major development.

The history of the study of the Plantagenet Group prior to 1954 is well presented by Clarke and Phillips (1954) and will not be repeated here. Until 1954 the only well preserved fossils studied were sponge spicules and the accepted age of the sediments at that time was Miocene.

Singleton (1954) seems to have been the first to dispute the Miocene age, considering the sediments to be Upper Eocene because of the occurrence of the nautiloid *Aturia clarkei* Teichert, elsewhere of Upper Eocene age. Palynological investigations by Balme and Churchill (1958), indicated a Lower Oligocene or Upper Eocene age for the 400 feet of sediments in Rollo's Bore, Coolgardie, which have been correlated with the Plantagenet Group. They conducted their studies on the only other well preserved fossils apart from the sponges. Glenister and Glover (1958) also gave a Middle or Upper Eocene age on the basis of the nautiloid *Teichertia prora*. McWhae *et al.* (1958) and Glaessner (*in* Lotze, 1959) also quoted an Upper Eocene age, probably on the basis of the nautiloids, but Sofoulis (1958) still used the Lower Miocene age. Hodgson, Quilty and Rutledge (1961) did the first detailed study on a part of the Plantagenet Group. The area studied was mainly Cape Riche, 70 miles east of Albany, but foraminifera and echinoids from Nanarup near Albany, were also examined and formed the basis for an Upper Eocene age determination. Wyatt (1962) in his search for commercial lime deposits in the Albany district took a sample (his sample No. 13026) from the lime quarry at Nanarup from which also comes most of the material studied for this paper. He apparently mistook it for the Coastal Limestone so prevalent on this coastline. Kay *et al.* (1963) quoted my 1961 (*in* Hodgson, Quilty and Rutledge, 1961) Upper Eocene determination based on foraminifera. Cockbain (1967) reported *Asterocyclina* from Neridup, near Esperance.

The limestone at Nanarup contains an extensive fauna of foraminifera, echinoids and bryozoa with many brachiopods, pelecypods, gastropods, occasional fish teeth, nautiloids and associated calcareous algae.

The locality of the Nanarup quarry is shown in Figure 1. The coordinates of the quarry are:

Latitude—34° 58′ 47″S.

Longitude—118° 02′ 12″E.

Rock specimens and foraminifera identified herein are housed in the collection of the Geology Department, University of Western Australia, and the number following the symbol U.W.A.G.D. represents the number of the specimen in that collection.

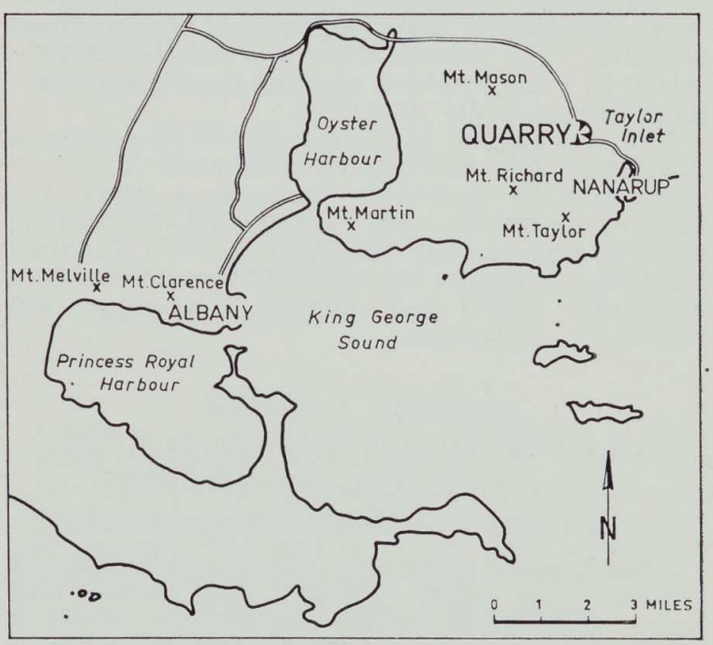

Figure 1.—Locality map.

Several spellings of the locality are in existence. The Military Survey Mt Manypeaks (No. 478) Map sheet has the name spelled Nannarup. The same series Albany (No 480) Map sheet has the name spelled Nannerup, and the latest road map put out by the Ampol Petroleum Co. spells it Nanarup. The Nomenclature Advisory Committee of the Western Australian Lands and Surveys Department advises me that the latter spelling is correct and it is adopted here.

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The limestone at Nanarup

The limestone (actually an almost unconsolidated bryozoal calcarenite) is lithologically very different from most other rock types so far recorded from the Plantagenet Group and it is desirable to show that it is in fact, part of those sediments.

The limestone is Upper Eocene in age. Other areas of the Plantagenet Group are also Upper Eocene in age, this dating based on nautiloids (Singleton, 1954; Glenister and Glover, 1958). Thus there is the evidence of age.

The limestone is surrounded by Precambrian basement and has not been seen in contact with other parts of the Plantagenet Group. No structural disruptions are known between the limestone and the Plantagenet Group a few miles to the east. Thus since the limestone and the Plantagenet Group to the east have similar elevations above sea level, it is logical to equate them.

The Coastal Limestone is generally regarded as being quite young (Pliocene (?), Pleistocene—Recent) and is thus distinct. However, the Eocene limestone at Nanarup has been confused with the younger deposit at least once (Wyatt, 1962) and it is necessary to point out the difference. The Coastal Limestone is generally a subaerial calcarenite whereas the Eocene material is marine. The Coastal Limestone is composed commonly of at least 50% rounded, well sorted wind blown quartz sand, whereas the Nanarup deposit has a very high calcium carbonate content and any detrital fragments found in the sediment are angular, poorly sorted rock fragments often containing quite fresh feldspar. The younger deposit is usually characterised by cross bedding whereas the Eocene sediment is essentially unbedded.

The extent and thickness of the limestone is unknown. The area known covers only about 25 acres and the maximum thickness is about 15-20 feet. Cockbain (1968) formalised the nomenclature, naming the limestone as the Nanarup Limestone Member of the Werillup Formation. McTavish (1966) had referred invalidly to the Nannarup Limestone.

Systematic descriptions

Order FORAMINIFERIDA Eichwald, 1830.

Superfamily GLOBIGERINACEA

Nomenclature of planktonic foraminifera

After having examined large populations of *Globigerapsis index* (Finlay) and having had some experience with *Globigerina unicava* (Bolli, Loeblich and Tappan) and its allies, I consider that many planktonic foraminifer genera and species are based on gerontic, reproductive or some such specifically nondiagnostic characters, and as such, have no taxonomic significance, even though they may have some empirical stratigraphical significance. Hence *Catapsydrax, Globigerinita, Tinophodella, Globigerinatheka, Inordinatosphaera* etc are possibly all biologically invalid genera, and the species of those genera are generally the same thing as previously described species of genera such as *Globigerina*. The only generic names used herein are *Globanomalina, Globigerapsis, Globigerina* and *Turborotalia*. The reasons for dismissal of so many generic names will be shown when I discuss *Globigerapsis index* (Finlay) in some detail.

Present-day workers are splitting planktonic foraminifera into finer and finer subdivisions so that trinomial nomenclature is now almost the rule. By splitting taxa into finer units, we should pave the way for finer and finer stratigraphic subdivisions and correlation. Unfortunately, the good to be obtained from such subdivision is often lost because the taxa are very poorly defined and badly illustrated. Also with so many workers in the field, synonymies become rather large, and often very subjective.

In trinomial nomenclature, the ultimate subdivision is usually termed a subspecies. This term should not be used. The International Commission on Zoological Nomenclature defines a subspecies as—

(1) a category of the species group subordinate to species; or

(2) an individual taxon of the category "subspecies".

Neither of the ICZN definitions covers the complex situation which has evolved in naming planktonic foraminifera. "Subspecies" should be retained for parts of species which are separated from one another geographically, climatically or by some factor which can be recognised as constituting a genetic barrier of non specific magnitude, rather than for parts of one continuous interbreeding population, members of which cannot be distinguished from one another until the complete adult form is reached, and which genetically are completely intergradational. *Globigerina euapertura* Jenkins, simply by the addition of a bulla, changes genus and species to become *Catapsydrax unicavus* Bolli, Loeblich and Tappan. This is biologically absurd, so the name *C. unicavus,* having priority, is the name which should be used. However, *Catapsydrax* must then be a junior synonym of *Globigerina,* so the species becomes *Globigerina unicava* (Bolli, Loeblich and Tappan). Some "lumpers" would place *G. ampliapertura* Bolli and *G. unicava* in synonymy with *G. apertura* Cushman.

For some purposes, it is useful to give names to these morphotypic subdivisions of *G. apertura*. These cannot be called subspecies, because what was previously called *G. euapertura* still develops into the nominally different morphological subdivision previously called *Catapsydrax unicavus*. The terms "variety" in the sense of Sylvester-Bradley (1951) or "form" or "forma" in the sense of Wade (1964) or Hofker (1959) seem quite good answers to the problem. The name "variety" or "form" seems to have no ontogenetic, gerontic or reproductive implications, which "subspecies" does. Because Wade and Hofker have both used "forma", it is used here, except that the anglicised version "form" is employed.

The classification adopted here is modified from those of Banner and Blow (1959) and Loeblich and Tappan (1961, 1964) and recognises

only the Families Hantkeninidae, Globigerinidae and Globorotaliidae among the Tertiary globigerinid foraminifera.

Family HANTKENINIDAE

Genus GLOBANOMALINA Haque, 1956

Globanomalina micra (Cole), 1927

Fig. 6, no. I, II

Nonion micrus Cole 1927, p. 22, pl. 5, fig. 12.

? *Nonion iota* Finlay 1940, p. 456, pl. 65, figs. 108-110.

Globigerinella micra (Cole); Crespin 1956, p. 31.

Hastigerina micra (Cole); Bolli 1957B, p. 161, pl. 35, figs. 1a-2b.

"Globigerinella" iota (Finlay); Hornibrook 1958A, pp. 27-29, pl. 1, figs. 22-24.

Globigerina iota (Finlay); Hornibrook 1958B, p. 664, 665, figs. 20, 24.

Pseudohastigerina micra (Cole); Banner and Blow 1959, p. 19, 20, pl. 3, figs. 6a, b. text figs. 4g-i.

Hastigerina micra (Cole); Ludbrook 1961, p. 21.

Globigerina iota (Finlay); Hornibrook 1961, p. 148.

Pseudohastigerina micra (Cole); Blow and Banner (*in* Eames *et al.*) 1962, p. 129, 130, pl. 16, figs. E. F. text fig. 9, x-xii.

Globanomalina micra (Cole); Loeblich and Tappan 1964, p. C665, fig. 531, 6-8.

Pseudohastigerina micra (Cole); Wade 1964, p. 274, 279, etc., pl. 1, fig. 5.

Nonion iota Finlay Jenkins 1965B, pl. 2, fig. 9.

Globigerina pseudoiota Hornibrook; Jenkins 1965B, pl. 2, fig. 10.

Globanomalina micra (Cole); Jenkins 1965A, p. 1092.

Remarks

The ultimate chamber of this species is often modified, either much more inflated and larger than the penultimate, or volumetrically part of the normal growth series but with the centre of the chamber displaced proximally to a position closer to the proloculus than it would be if it was part of the normal growth series. In the latter case, the proximal extremities of the chamber cover much of umbilicus. This modified ultimate chamber is probably equivalent to the bulla of other globigerinid species.

One hundred and one specimens of the species are present in the sample. Average maximum diameter is 0.25 mm ranging from 0.17 to 0.32 mm. Approximately two thirds of the specimens have six chambers in the last whorl, one tenth have seven, and the rest have five.

Maximum diameter of figured specimens—

(a) 0.25 mm

(b) 0.25 mm.

Repository:

(a) U.W.A.G.D. 59502

(b) U.W.A.G.D. 59503.

Family GLOBIGERINIDAE

Genus GLOBIGERINA d'Orbigny, 1826.

Globigerina cf *africana* (Blow and Banner), 1962.

Fig. 6, No. III, IV.

cf *Globigerinita africana* Blow and Banner (*in* Eames *et al.*) 1962, p. 105, 106, pl. 15, figs. A-C.

Remarks

The identification is tentative as a bulla is absent and the apertural characters are not preserved. Only a single specimen was recovered.

Maximum diameter of figured specimen 0.39 mm.

Repository: U.W.A.G.D. 59505.

Globigerina ampliapertura form *ampliapertura* Bolli, 1957.

Fig. 6, No. V-VIII.

Globigerina ampliapertura Bolli 1957A, p. 108, pl. 22, figs. 5a-7b.

Globigerina cf *ampliapertura* Bolli; Ludbrook 1961, p. 21.

Globigerina ampliapertura ampliapertura Bolli; Blow and Banner (*in* Eames *et al.*) 1962, p. 83, 84, pl. 11, figs. A-D.

Globigerina ampliapertura Bolli; Wade 1964, p. 274, 279, pl. 1, figs. 13-15, 17, 18.

Globigerina ampliapertura Bolli; Jenkins 1965A, p. 1092, fig. 2.

Globigerina ampliapertura Bolli; Taylor 1966, p. 33.

Globigerina ampliapertura Bolli; Lindsay 1967, p. 103, pl. 1, fig. 17.

Remarks. In the sample studied, 382 specimens of this form were obtained. 64% are sinistrally coil and 36% dextrally coiled. Average maximum dimension is 0.34 mm, with a size range from 0.19-0.56 mm. A histogram of maximum diameters in the species is shown in Figure 2.

As many specimens in the sample are bullate, one specimen was sectioned to determine the structure of the bulla. This was also done to specimens of *"Globigerinoides" index*. Similar results were obtained in each case. In all bullate forms sectioned, the bulla wall is approximately half as thick as the wall of the chamber preceding it, the pores have a diameter half that of the pores in the preceding chamber and the pores are much more closely spaced than in the preceding chamber.

Measurements taken on the section of *G. ampliapertura* are given below.

Wall thickness—

Bulla 10-13μ

Preceding chamber 20-23μ

Pore spacing—

Bulla 5-7μ

Preceding chamber c.10μ

Pore diameter—

Bulla c. 1μ

Preceding chamber 2-3μ

When one examines the histograms of maximum diameters of this species, it is evident that all bullate forms are restricted to a group lying to the right of the depression in the curve. That is, overall, the bullate forms are larger. Two possibilities immediately present themselves.

(a) The species may be dimorphic,

(b) The bulla may simply grow on large specimens and be a gerontic chamber.

If the species does exhibit dimorphism, it is probable that the bulla has something to do with the reproductive cycle, the larger specimens being possibly microspheric (see later, under *Globigerapsis index*). Maximum diameter of figured specimens (a) complete speciment 0.40 mm.

(b) section 0.51 mm.

Repository: (a) U.W.A.G.D. 59506.

(b) U.W.A.G.D. 59536.

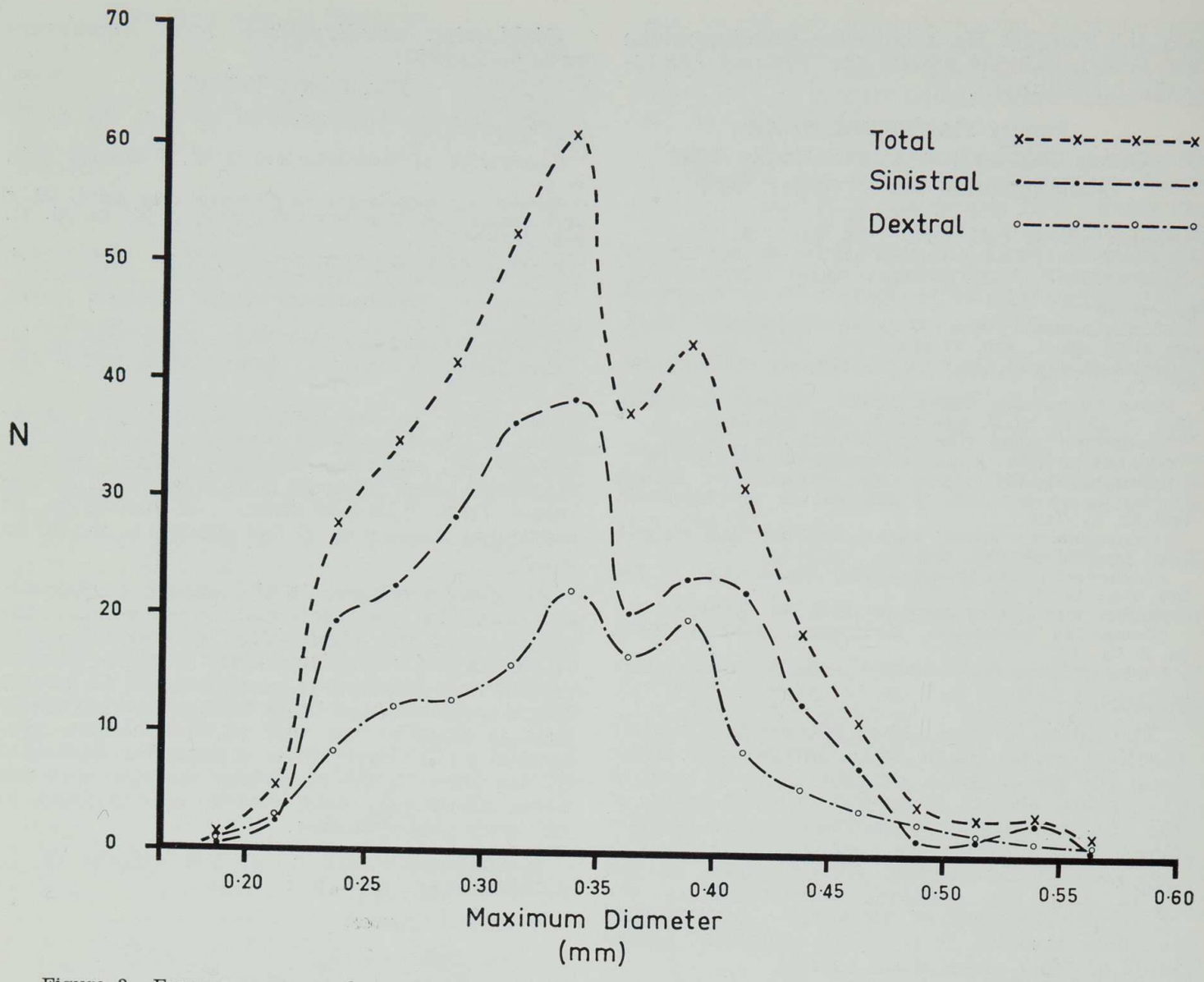


Figure 2.—Frequency curve of maximum diameters—*Globigerina ampliapertura* form *ampliapertura* Bolli.

Globigerina ciperoensis form *angustiumbilicata* Bolli, 1957.

Fig. 6, no. IX-XI

Globigerina ciperoensis angustiumbilicata Bolli 1957A, p. 109, pl. 22, figs. 12, 13; pl. 36, fig. 6.

Globigerina angustiumbilicata Bolli; Blow 1959, p. 172, pl. 7, fig. 33.

Globigerina angustiumbilicata Bolli; Jenkins 1960, p. 350, pl. 1, figs. 2a-c.

Globigerina angustiumbilicata Bolli; Blow and Banner (*in* Eames *et al.*) 1962, p. 85, pl. 9, figs. X-Z.

Globigerina angustiumbilicata Bolli; Wade 1964, p. 274, 279, etc., pl. 1, fig. 11.

Globigerina angustiumbilicata (Bolli); Reed 1965, p. 81, pl. 13, figs. 1-6.

Remarks

Apparently unrecorded previously is the occasional presence of bullae in this species. Of 88 specimens seen in this sample, 27 had a well developed bulla. In the sample, 82 specimens (93%) are dextrally coiled and six (7%) sinistrally coiled. Average maximum diameter is 0.25 mm. with a size range from 0.17-0.32 mm.

Maximum diameter of figured specimen 0.21 mm.

Repository: U.W.A.G.D. 59507.

Globigerina ciperoensis form *basaapertura* Quilty new form.

Fig. 6, no. XII-XV

Diagnosis

Globigerina ciperoensis with $4\frac{1}{2}$-5 chambers in final whorl, giving a subpentagonal, equatorial profile; distinguished by its size (0.22-0.29 mm.) and low aperture.

Description

Test small, a low trochospire. Subpentagonal in equatorial profile, flat semiovoid in axial. Dorsal surface flat or slightly convex. Periphery strongly lobulate. Surface uniformly hispid with fine granular appearance. Test consists of three whorls of globular chambers, increasing uniformly in size at a rate less than *G. praebulloides,* or any form except *G. c.* form *ciperoensis,* to which it is similar. First whorl consists of six or seven chambers, last two whorls with $4\frac{1}{2}$-5 chambers each. Chambers strongly appressed in first whorl but becoming less appressed later. Chambers uniform in shape in last two whorls, with radial and tangential dimensions approxi-

mately equal. Radial sutures straight on both ventral and dorsal sides, more depressed on ventral side than on dorsal.

Spiral suture depressed and lobulate. Aperture a very low arch, between proximal part of penultimate chamber and most ventral posterior part of fifth last chamber; opens into broad deep, irregular pentagonal umbilicus; without lip or rim; apertural face not flattened. Apertures of previous chambers often to some extent continuous with that of ultimate chamber. Ultimate chamber often modified to a small bulla on ventral surface of test.

Remarks

The form is described from a holotype and six paratypes. In the fauna examined, 14 specimens were present, ranging in maximum diameter from 0.22 to 0.29 mm. with an average of between 0.25 and 0.26 mm. Only one sinistrally coiled specimen was seen.

It is similar to *G. c.* form *ciperoensis* Bolli in possessing the same loose growth spiral, surface and wall structures and differs in size, apertural characters and time range. Bolli's (1954) definition of *G. ciperoensis* included a size range of 0.3-0.4 mm. for the maximum diameter of the species and so far I can find no record of this being extended. The aperture of the new form is a low arch whereas that of *G. c.* form *ciperoensis* is a high arch. *G. c.* form *ciperoensis* is not known from Upper Eocene rocks.

G. ciperoensis can be distinguished from *G. ouachitaensis* Howe and Wallace on the basis of number of chambers in the final whorl. The former has about five the latter about four. Thus *G. ouachitaensis gnaucki* Blow and Banner is probably better placed in *G. ciperoensis*. *G. ciperoensis* form *gnaucki* differs from the new form in having a high arched aperture.

G. c. form *angustiumbilicata* Bolli is more involute and has a more restricted umbilicus than the new form. The aperture of the new form is wider and lower than in *G. c.* form *angustiumbilicata*. It also does not possess a lip—a characteristic of *G. c. angustiumbilicata*.

In some respects the growth spiral is similar to that of *Globorotalia postcretacea* (Myatliuk). However, the latter has a much less perforate, smooth test, an apertural lip and a smaller test size (0.12 mm).

It differs from *Globorotaloides suteri* Bolli, in having no globorotaline initial stage. The latter species has been recorded in rocks of this age as close as New Zealand (Jenkins, 1965A) and South Australia (Wade, 1964).

The name is derived from the Latin *basa* (f)—low + *apertura* (f)—aperture or hole.

Maximum diameter of holotype 0.26 mm.

Repository:

(a) Holotype U.W.A.G.D. 59513.

(b) Paratypes U.W.A.G.D. 59514—59518, 60593.

Globigerina (Catapsydrax) cf *echinata* (Bolli), 1957.

Fig. 6, No. XVI, XVII.

cf. *Catapsydrax echinatus* Bolli 1957B, p. 165, pl. 37, figs. 2-5.

Remarks

Only two specimens were recovered and thus description as a new species is inadvisable. They are both 0.24 mm. in maximum diameter, one sinistrally and one dextrally coiled.

They are very similar to *G. echinata*, but small sample and poor preservation make accurate identification difficult.

Repository: U.W.A.G.D. 59508.

Globigerina gortanii form *praeturritilina* Blow and Banner, 1962

Fig. 6, No. XVIII-XX

Globigerina turritilina praeturritilina Blow and Banner (*in* Eames *et al.*) 1962, p. 99, pl. 13, figs. A-C.

Globigerina gortanii Borsetti; Blow and Banner (*op. cit.*) p. 146.

Globigerina praeturritilina Blow and Banner; Jenkins 1965A, fig. 2.

Remarks

As only two specimens of this species were recovered, its variation in the sample is unknown. Of the specimens recovered, one is sinistrally coiled. Both are 0.29 mm in maximum diameter.

The specimens found here are smaller than typical *G. g.* form *praeturritilina*. Also the well defined deep umbilicus is absent. The aperture faces the umbilical position squarely and not slightly obliquely. However, Blow and Banner (1962, *op. cit.*) state that when the umbilicus is less open, the primary aperture is a higher, more semicircular arch, a condition which seems to apply here. No aborted end chamber was seen.

Repository: U.W.A.G.D. 59504.

Globigerina jenkinsi Quilty new species.

Fig. 6, No. XXI, XXII

Diagnosis

Globigerina 0.20-0.30 mm in diameter. Final whorl of three chambers, the aperture of the ultimate chamber sitting symmetrically astride the penultimate and ante penultimate chambers, and with a finely hispid wall with a fine granular appearance.

Description

Test small, a low to moderately high trochospire. Equatorial profile rounded subtriangular, axial profile reniform, Periphery moderately to strongly lobulate. Surface uniformly finely hispid, finely perforate and fairly thin. Ten to twelve chambers arranged in about three involute whorls, five chambers in the first, four in the second and three in the third. Chambers reniform in the early part of the second whorl but increasing very rapidly in size and becoming very globular. Appressed chambers reniform, becoming embracing with the assumption of a globular habit. Spiral suture strongly lobulate, initially very little depressed, but distinctly so at maturity. Dorsal intercameral sutures straight, radial, and little depressed in the first 1½ whorls but becoming curved posteriorly distally. and more depressed with the assumption of the globular, embracing habit.

Aperture intraumbilical, variable in shape from a symmetrical small low arch to a small high arch; shared equally by penultimate and antepenultimate chambers; situated in a flattened apertural face and bordered by a poorly to very well developed marginal rim. Umbilicus shallow, triangular and poorly defined. No bulla was seen on any specimens examined.

Remarks

Globigerina brazieri Jenkins is very similar to the new species, the difference though small, being distinctive. The new species is also known as yet only from the Upper Eocene while *G. brazieri* occurs within the Lower Miocene. It is slightly more involute than *G. brazieri*, the aperture is relatively a little lower, and the apertural rim is generally not so distinct. The granular appearance of the wall also seems a little finer.

This distinctive little species has a similar growth form to *G. tripartita* Koch but is distinctly smaller. The latter species appears to have a size range of 0.55-0.75 mm. whereas the new species ranges from 0.20-0.30 mm. with an average value of 0.27 mm. Of the 18 specimens recovered, 15 (84%) are dextrally coiled.

The species is named from a holotype and six paratypes. It is named in honour of Dr. D. G. Jenkins, for his work on Australasian planktonic foraminifera.

Maximum diameter of holotype 0.26 mm.

Repository: (a) Holotype U.W.A.G.D. 59525

(b) Paratypes U.W.A.G.D. 59526-59531.

Globigerina linaperta form *linaperta* Finlay, 1939.

Fig. 6, no. XXIII-XXV

Globigerina linaperta Finlay 1939B, p. 125, pl. 13, figs. 54-57.

Globigerina linaperta Finlay; Hornibrook 1958A, p. 33, pl. 1, figs. 19-21.

Globigerina linaperta Finlay; Carter, 1958B, pp. 50-51, pl. 5, figs. 46, 47.

Globigerina linaperta Finlay; Ludbrook 1961, p. 20, pl. 1, fig. 8.

Globigerina linaperta linaperta Finlay; Blow and Banner (*in* Eames *et al.*) 1962, p. 85, pl. 11, fig. H.

Globigerina linaperta Finlay; Wade 1964, p. 274, 279.

Globigerina linaperta Finlay; Jenkins 1965A, fig. 2, p. 1092, etc.

Globigerina linaperta Finlay; Lindsay 1967, p. 105, pl. 1, figs. 23, 24.

Remarks

In this sample, 44 specimens were recovered, of which 26 (60%) are dextrally coiled and 18 (40%) are sinistrally coiled. Average maximum diameter is 0.26 mm. with a size range of 0.20-0.37 mm.

Hornibrook (1958A) refigured the holotype and redescribed the species, noting the fact that a distal flattening of the chambers is a feature of the species. Most descriptions do not mention this distal flattening of the chambers and similarly, few illustrations show it.

Hornibrook (1961, p. 145) gave the time range of *G. linaperta* as Lower to Upper Eocene. He suggested, as did Blow and Banner (*in* Eames *et al.*, 1962, p. 87-88), that *G. linaperta* has developed from *G. triloculinoides*. If this is so, it is to be expected that intermediate forms existed before the Eocene rendering distinction between the species difficult and subjective and accounting for much of the confusion.

Maximum diameter of figured specimen 0.27 mm.

Repository: U.W.A.G.D. 59509.

Globigerina martini (Blow and Banner), 1962.

Fig. 6, no. XXVI-XXVIII

Globigerinita martini martini Blow and Banner (*in* Eames *et al.*) 1962, pp. 110-111, pl. 14, fig. 0.

Catapsydrax martinii (Blow and Banner); Jenkins 1965A, fig. 2.

Remarks

Of the 16 specimens in the sample, all but one are dextrally coiled. Average size of specimens is 0.25 mm. with a range from 0.20-0.32 mm. Maximum diameter of figured specimen 0.31 mm.

Repository: U.W.A.G.D. 59510.

Globigerina officinalis Subbotina, 1953.

Fig. 7, no. XXIX-XXXI

Globigerina officinalis Subbotina 1953, p. 78, pl. 11, figs. 1a-2c., 6a-7c.

Globigerina officinalis Subbotina; Blow and Banner (*in* Eames *et al.*) 1962, p. 88, pl. 9, figs. A-C.

Globigerina officinalis Subbotina: Wade 1964, p. 279, pl. 1, fig. 3.

Remarks: The statement of Blow and Banner (*in* Eames *et al.*, 1962, p. 88) that the chamber shape in this species is constant, is apparently not quite true. Throughout ontogeny the chambers become more globular and at the same time more appressed. Their illustration (Pl. IX, figs. A-C) shows the change. Another fact not illustrated by them is that the first whorl may contain as many as seven chambers.

Of the 33 specimens in the sample, 29 (88%) are dextrally coiled. Average size is 0.27 mm with a size range of from 0.18-0.35 mm. Maximum diameter of figured specimen 0.30 mm.

Repository: U.W.A.G.D. 59511.

Globigerina ouachitaensis form *ouachitaensis* Howe and Wallace, 1932.

Fig. 7, No. XXXII

Globigerina ouachitaensis Howe and Wallace 1932, p. 74, pl. 10, figs. 7a-b.

Globigerina ouachitaensis ouachitaensis Howe and Wallace; Blow and Banner (*in* Eames *et al.*) 1962, p. 90, pl. 9, figs. D, H-K.

Globigerina ouachitaensis Howe and Wallace; Wade 1964, p. 274, etc., pl. 1, fig. 4.

Globigerina ouachitaensis Howe and Wallace; Jenkins 1965A, p. 1091, fig. 2.

Remarks: One of the most characteristic features of the species is the high trochospiral growth form. The Western Australian specimens have a lower trochospiral growth form than the holotype but come close to the holotype spire height and are regarded here as intergradational.

The sample studied consists of 14 specimens of this form, 12 of which are dextrally coiled. Average maximum diameter is 0.28 mm with a range from 0.20 to 0.35 mm. Maximum diameter of figured specimen 0.30 mm.

Repository: U.W.A.G.D. 59512.

Globigerina praebulloides Blow, 1959.

Fig. 7, No. XXXIII, XXXIV

Globigerina praebulloides Blow 1959, p. 180, pl. 8, figs. 47a-c, pl. 9, fig. 48.
Globigerina bulloides d'Orbigny; Ludbrook 1961, p. 19.
Globigerina praebulloides Blow; Blow and Banner (*in* Eames *et al.*) 1962, pp. 92-94, pl. 9, figs. O-W.
Globigerina bulloides d'Orbigny; Wade 1964, p. 274 *et seq.*, pl. 1, fig. 6.
Globigerina bulloides d'Orbigny; Jenkins 1965A, p. 1092, fig. 2.
cf. *Globigerina bulloides* d'Orbigny; Lindsay 1967, p. 104, pl. 1, fig. 16.

Remarks

The three forms listed by Blow and Banner (*in* Eames *et al.*, 1962)—i.e. *Globigerina praebulloides praebulloides, G. p. occlusa,* and *G. p. leroyi*—are present although *G. p. leroyi* is somewhat doubtfully identified. While agreeing that they are probably typological forms only, and most probably part of one interbreeding population, I feel that such a subdivision of *G. praebulloides* is worthwhile. Changes in fossil populations of the ratios of the three forms to each other may eventually fulfil the dual roles of (a) aiding accurate interregional correlation and (b) providing an evolutionary series.

In the sample studied the following measurements were noted.

	G. p. praebulloides	*G. p. occlusa*	*G. p. leroyi*
Number of specimens	41	42	7
Number (%) of specimens coiled dextrally	35 (85)	40 (95)	7 (100)
Average maximum diameter (mm)	0.28	0.27	0.25

Maximum dimension of figured specimen: *Globigerina praebulloides* form *praebulloides*= 0.25 mm.

Repository: U.W.A.G.D. 59519.

Globigerina senilis Bandy, 1949.

Fig. 7, No. XXXV, XXXVI

Globigerina ouachitaensis Howe and Wallace var. *senilis* Bandy 1949, p. 121, pl. 22, figs. 5a-c.
Globigerina senilis Bandy; Blow and Banner (*in* Eames *et al.*) 1962, p. 95, 96, pl. 11, figs. R-U.

Remarks: Of 31 specimens recovered, 30 (97%) are dextrally coiled. Average maximum diameter is 0.26 mm with size range from 0.22-0.32 mm. Maximum diameter of figured specimen 0.29 mm.

Repository: U.W.A.G.D. 59522.

Globigerina tripartita form *tapuriensis* Blow and Banner, 1962.

Fig. 7, no. XXXVII-XXXIX

Globigerina tripartita tapuriensis Blow and Banner (*in* Eames *et al.*) 1962, p. 97, 98, pl. 10, figs. H-K.
? *Globoquadrina tripartita* (Koch); Jenkins 1965A, fig. 2.

Variation and Remarks

Only two specimens were recovered. They are 0.52 and 0.57 mm in diameter. The larger one is figured.

The specimens found here are very similar to those figured and described as *G. tripartita tapuriensis* by Blow and Banner *(op. cit.)* Their remarks (p. 98) however, would indicate that it should not be found in rocks older than Oligocene. There seems little doubt concerning its identity in this sample. The two samples differ apparently only in that the aperture has no lip in the Nanarup specimens. However, the specimen figured by Blow and Banner apparently does not have one either.

Blow and Banner *(op. cit)* place *G. rohri* Bolli in synonymy with *G. tripartita* Koch. Dr. H. Bolli has kindly supplied me with topotypes of *G. rohri* Bolli and my specimens appear to represent a different species from the specimens supplied. The wall of *G. rohri* has a more coarsely granular appearance than in the species found here, the early chambers on the dorsal surface are much more distinct, the coiling arrangement is slightly tighter, and there are well developed short spines surrounding the aperture. Blow and Banner *(in* Eames *et al.*, 1962, p. 96-97) suggested that the spines around the aperture are simply a result of better preservation in this vicinity, similar spines from the entire test surface having been abraded off. I think this explanation an unlikely one, the topotype specimens being apparently quite well preserved with no signs of abrasion. I would thus consider *G. rohri* and *G. tripartita* to be distinct species. Maximum diameter of figured specimen 0.57 mm.

Repository: U.W.A.G.D. 59523.

Globigerina yeguaensis cf form *yeguaensis* Weinzierl and Applin, 1929.

Fig. 7, no. XL, XLI

cf *Globigerina yeguaensis* Weinzierl and Applin 1929, p. 408, pl. 43, figs. 1a, b.
cf *Globigerina yeguaensis yeguaensis* Weinzierl and Applin: Blow and Banner (*in* Eames *et al.*) 1962, p. 99, 100, pl. 12, figs. H-M.

Remarks

G. yeguaensis yeguaensis and *G. y. pseudovenezuelana* are possibly both represented here, but very good preservation in the umbilical region appears to be necessary to distinguish them. The species is rare and apparently not as well preserved as many others here. Most specimens seem closer to *G. y. yeguaensis.*

Nine specimens of the species were found—all dextrally coiled. Maximum diameter ranges from 0.20 to 0.30 mm. with an average value of 0.26 mm.

Maximum diameter of figured specimen 0.26 mm.

Repository: U.W.A.G.D. 59524.

Genus GLOBIGERAPSIS Bolli, Loeblich and Tappan, 1957.

Globigerapsis index (Finlay), 1939.

Fig. 7, no. XLII-XLVIII

Globigerinoides conglobata (Brady); Glaessner 1937, p. 29, pl. 1, fig. 3.
Globigerinoides index Finlay 1939B, p. 125, pl. 14, figs. 85-88.
Globigerinoides index Finlay; Finlay and Marwick 1940, pp. 108-111.
Globigerinoides index Finlay; Finlay 1946, p. 240.

Globigerinoides index Finlay; Finlay 1947, p. 344.

Globigerinoides index Finlay; Dorreen 1948, p. 298, pl. 41, fig. 2.

Globigerinoides index Finlay; Grimsdale 1951, pp. 466, 468, 472.

Globigerinoides index Finlay; Todd *et al.* 1954, p. 678.

Globigerinoides index Finlay; Raggatt and Crespin 1954, pp. 128, 138.

Globigerinoides index Finlay; Crespin 1956, pp. 31, 40.

Globigerinoides index Finlay; Todd 1957, pp. 268, 270, pl. 70, figs. 5-7.

Globigerapsis index (Finlay); Bolli 1957B, p. 165, pl. 36, fig. 16 (? not figs. 14, 15, 17, 18).

Globigerinoides index Finlay; Carter 1958A, pp. 297-304.

Globigerinoides index Finlay; Carter 1958B, pp. 51, 52. pl. 7, figs. 64-66.

Globigerinoides index Finlay; Hornibrook 1958A, p. 34, pl. 1, figs. 11-14.

Globigerinoides index Finlay; Ludbrook 1958, p. 110.

Globigerapsis index (Finlay); Bermudez 1961, p. 1.251 pl. 8, fig. 6.

Globigerinoides index Finlay; Ludbrook 1961, p. 20.

Globigerapsis index Finlay; Ludbrook 1961, pl. 1, fig. 9.

? *Globigerina linaperta* Finlay; Ludbrook 1961, pl. 1., fig. 8.

? *Globigerapsis index* (Finlay); Pessagno 1961, p. 356, pl. 2, figs. 15-17.

Globigerapsis index (Finlay); Blow and Banner (*in* Eames *et al.*) 1962, pp. 124, 125, pl. 15, figs. G-H.

Globigerapsis index (Finlay); Wade 1964, p. 274, etc., pl. 1, figs. 9, 10.

Globigerapsis index index (Finlay); Jenkins 1965A, p. 1091 *et seq.*, fig. 2.

Globigerinoides (Globigerapsis) index Finlay; McTavish 1966, p. 15, etc., pl. 4, figs. 7, 13.

Globigerapsis index index (Finlay); Lindsay 1967, p. 105, pl. 1, fig. 19.

Description

Test moderately large (0.25-0.60 mm), globular, a moderately low trochospire. Equatorial profile variable, ovoid to roughly circular to subtriangular. Axial profile ovoid to subovoid. Periphery not lobulate but sharply indented by incised sutures. Surface with coarsely granular appearance. Chambers, in early whorls hard to distinguish due to granularity of surface and even in oils of R.I.=1.62—1.66 only the final two chambers of the second whorl become visible. Glauconitic internal moulds show four chambers in the first whorl, 3½ in second and three in the last. Test of about three whorls of chambers rapidly increasing in size, rate of increase probably greater in last whorl and late chambers of second whorl. Chambers usually globular, but ultimate chamber often only hemispherical or even more flattened. In small specimens ultimate chamber is largest, but in larger specimens it is often smaller than the penultimate. Tangential dimensions of chambers greater than radial. Chambers appressed with incised or "deep cleft" sutures. Spiral suture lobulate in second whorl but not in last, not depressed. Dorsal intercameral sutures nearly straight radial, not depressed but incised. Ventral intercameral sutures incised and straight. In small specimens or those in which last chamber is largest, generally only one aperture, ("*Globigerina*" type) a small high arch, opening over the antepenultimate—penultimate chamber suture into a very weakly developed umbilicus; usually symmetrical but occasionally markedly asymmetrical with highest point directed posteriorly. Some specimens (mainly those with modified ultimate chamber and some large specimens with ultimate chamber largest) may have two or three apertures often with a marked, thickened, elevated rim. Bullae are developed over each aperture in some specimens.

Variation and Remarks

In the sample studied, 1500 specimens were recovered. A random sample of 436 was tested statistically (see below). Average length (see below) is 0.37 mm with a range from 0.21 to 0.57 mm. Average breadth (see below) is 0.31 mm with a range from 0.18 to 0.47 mm. 95% of specimens are dextrally coiled.

Generic Concepts

In this study, generic differences are established on the following bases (see Figure 3).

(a) *"Globigerina"*—possesses a single umbilical aperture in the ultimate chamber. Ultimate chamber part of the normal growth spiral and normally largest chamber of specimen. [*Globigerina* of Banner and Blow, (1959, p. 5), and Loeblich and Tappan (1964, p. C669)].

(b) *"Globigerinoides"*—as for *"Globigerina"* but the ultimate chamber has two or three apertures—a large, umbilical one and one or two smaller ones on the dorsal side of the test, one always astride the suture of the antepenultimate and fourth last chambers, and another sometimes astride the suture of the penultimate and fourth last chambers. Accessory apertures are rare and difficult to find on chambers previous to the ultimate. [*Globigerinoides* of Banner and Blow (1959, p. 5), Loeblich and Tappan (1964, p. C670) etc.]

(c) *"Globigerapsis"*—differs from the two previous genera in possessing a modified ultimate chamber (see below) situated over the umbilicus of a *"Globigerina"* or *"Globigerinoides"* type individual. More than one aperture is present in this chamber and all apertures are of approximately equal size. The modified ultimate chamber is texturally similar to the preceding chambers of the normal growth spiral (probably Banner and Blow's (1959, p. 6) concept of *Catapsydrax*, and Bolli, Loeblich and Tappan's (1957, p. 33-34) view of *Globigerapsis*, but distinct from Loeblich and Tappan's (1964, p. C676) concept of *Catapsydrax* which has an umbilical bulla and is only questionably distinct from *Globigerinita*).

(d) *"Globigerinita"*—specimens derived from a *"Globigerina"* type by the addition of a single bulla very near to or covering the aperture of the previously formed chamber. The shape, size and position of this bulla vary widely. The bulla is texturally different from the preceding chamber (see below). (Concept essentially that employed by Blow and Banner [*in* Eames *et al.*, 1962, p. 102-105]).

(e) *"Globigerinatheka"*—analogous to *"Globigerinita"* but developed from a *"Globigerinoides"* or *"Globigerapsis"* type by the addition of a bulla to each aperture of the previously formed chamber. Removal by acid of the bullae and final chamber of a *"Globigerinatheka"* type shows that no bullae were developed before maturity. There may be more than one cycle of bulla development after maturity so that the

aperture of a bulla may in turn have a bulla over it. This concept embraces *Globigerinoita, Globigerinatheka Globigerinatella,* and *Inordinatosphaera* as indicated by Banner and Blow (1959, p. 6) Loeblich and Tappan (1964, p. C676-678) and Mohan and Soodan (1967). Jenkins (1965A, fig. 2) included *Globigerinatheka barri* Bronnimann in *G. index* as a subspecies.

In the sample, "genera" occurred in the ratio *"Globigerina": "Globigerinoides": "Globigerapsis": "Globigerinita": "Globigerinatheka":* 45:9:10½:7:1.

Statistics

To test the hypothesis that the "generic" groups are conspecific, a sample of 436 specimens was analysed statistically. For each specimen, two measurements were made. (See Figure 3 for explanation.)

(a) the length (L) taken as the maximum distance from the distal extremity of the ultimate chamber in the normal growth spiral to the distal extremities of the antepenultimate, and penultimate chambers in a line through the umbilicus. In *"Globigerina"* and *"Globigerinoides"* types this is the maximum dimension of the specimen. In other generic types, the final chamber, not being part of the normal growth spiral, is not considered, and the measurements are taken on the largest part of the test formed as a normal growth spiral.

(b) the breadth (B) taken as the maximum diameter at right angles to L, both L and B measured in a plane perpendicular to the axis of the growth spiral (see Figure 3).

The measurements L and B are considered significant, as any change of spire characteristics will make itself evident in these measurements.

Graphs of L against B and the calculated lines of best fit for each generic type, and *G. index* overall are presented in Figure 4. The superimposed lines of best fit are presented in Figure 5.

The measurements were analysed according to the method outlined by Imbrie (1956) and his symbols are used throughout.

Most of the statistics established by the method outlined by Imbrie are presented in Table 1. From these statistics, lines of the form $L = aB + b$ were formulated and are presented in Figure 5.

Where plotted, the lines of best fit were analysed to see if any significant difference in slope existed, using the formula

$$Z_1 = \frac{[a_1 - a_2]}{\sqrt{\sigma a_1^2 + \sigma a_2^2}}$$

where a_1 and a_2 represent the growth ratios of two lines being compared, and σa_1 and σa_2 are corresponding standard errors.

The results of these tests are illustrated in Table 2.

As all the calculated values of Z_1 are <1.96, the indication is that there is no significant difference (at 99% level) in slope between the lines representing the "generic" groups.

As there is no significant difference between the *slopes* of lines of best fit, Imbrie outlines a further test, to test the hypothesis that the growth lines characterising the populations from which the two samples are drawn, are identical over the size ranges represented in the samples, by using the formula.

$$z_2 = \frac{B_0 (a_1 - a_2) + (b_1 - b_2)}{\sqrt{\sigma a_1{}^2 (B_0 - \bar{B}_1)^2 + \sigma a_2{}^2 (B_0 - \bar{B}_2)^2}}$$

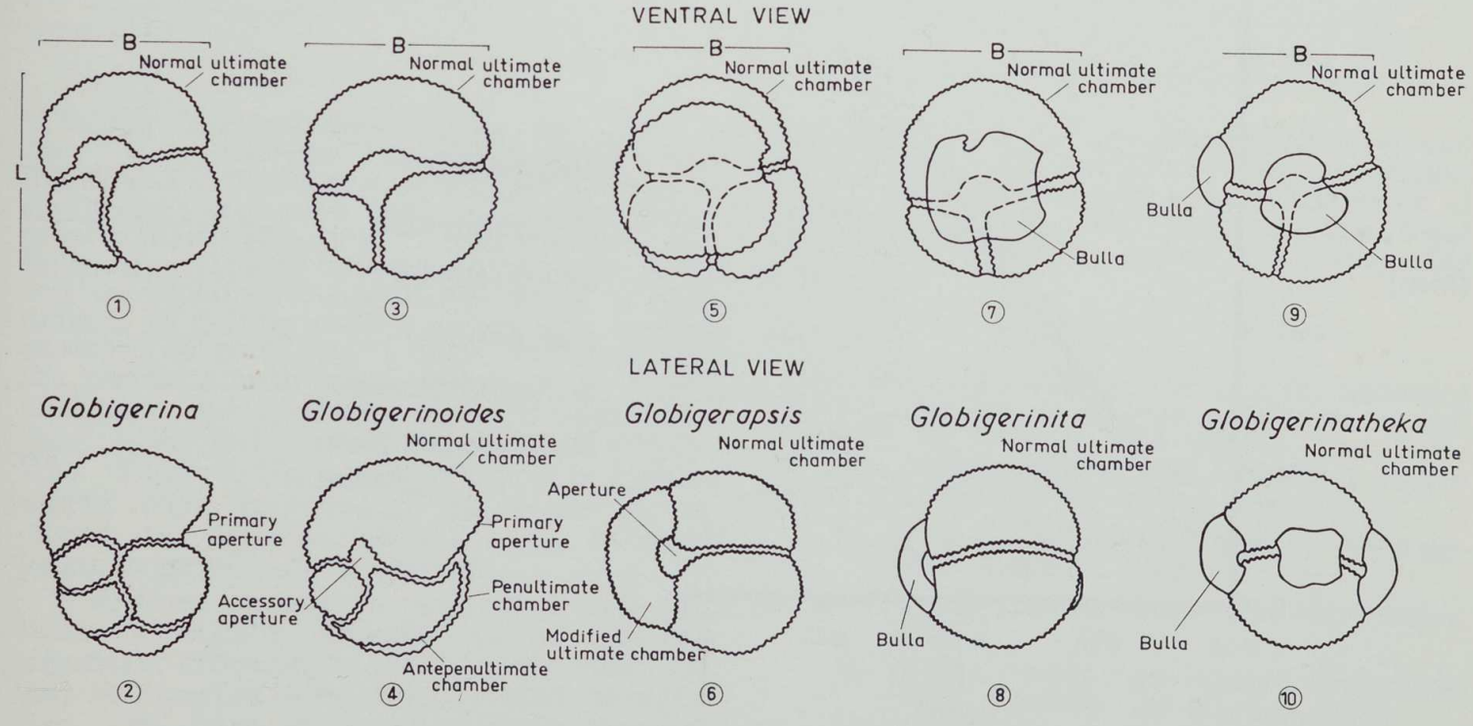
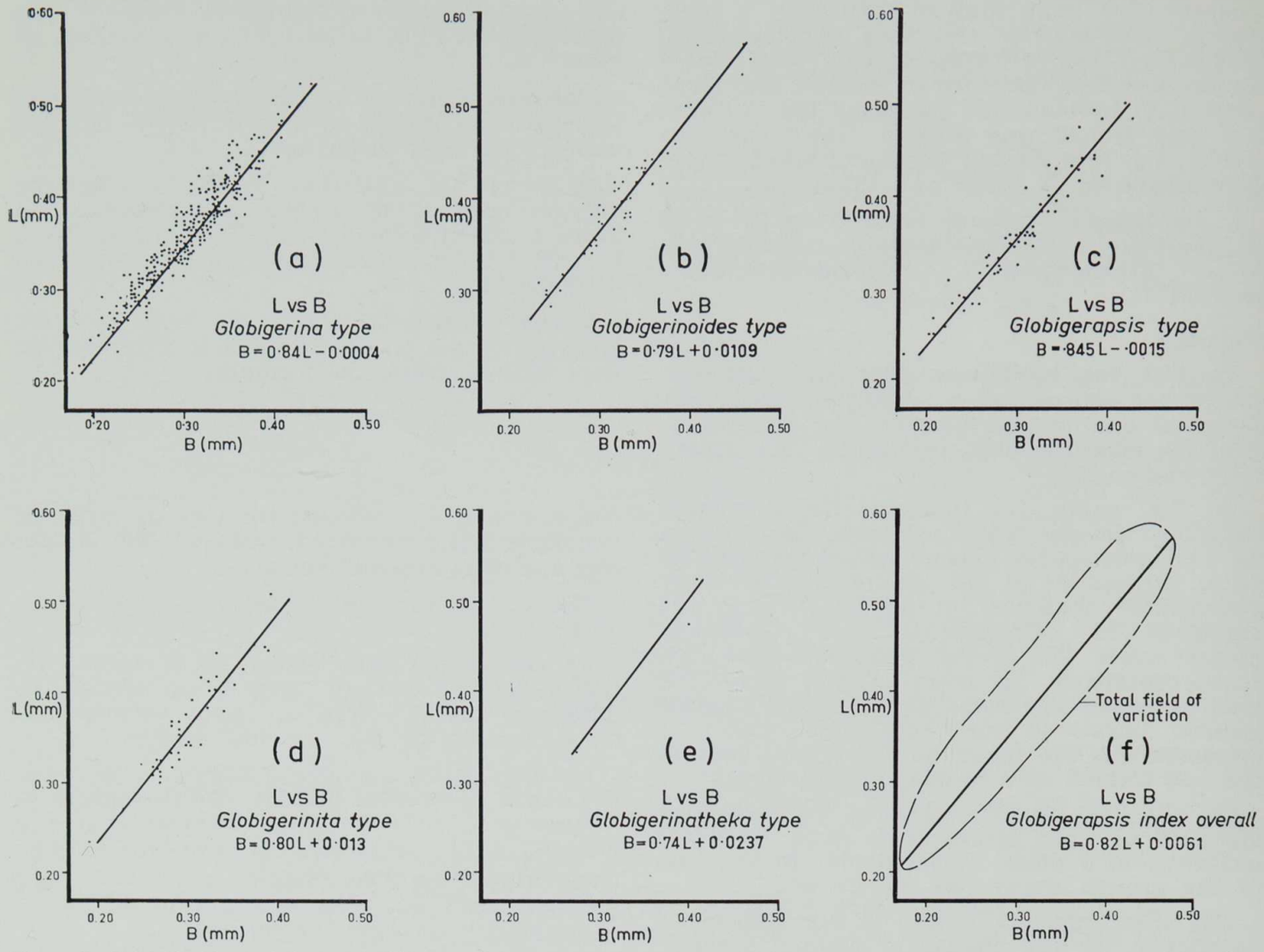


Figure 3.—Terminology used in discussing *Globigerapsis index* (Finlay).



Fiure 4.—Distribution of Length (L) and Breadth (B) for various "generic" groups within *Globigerapsis Index* (Finlay).

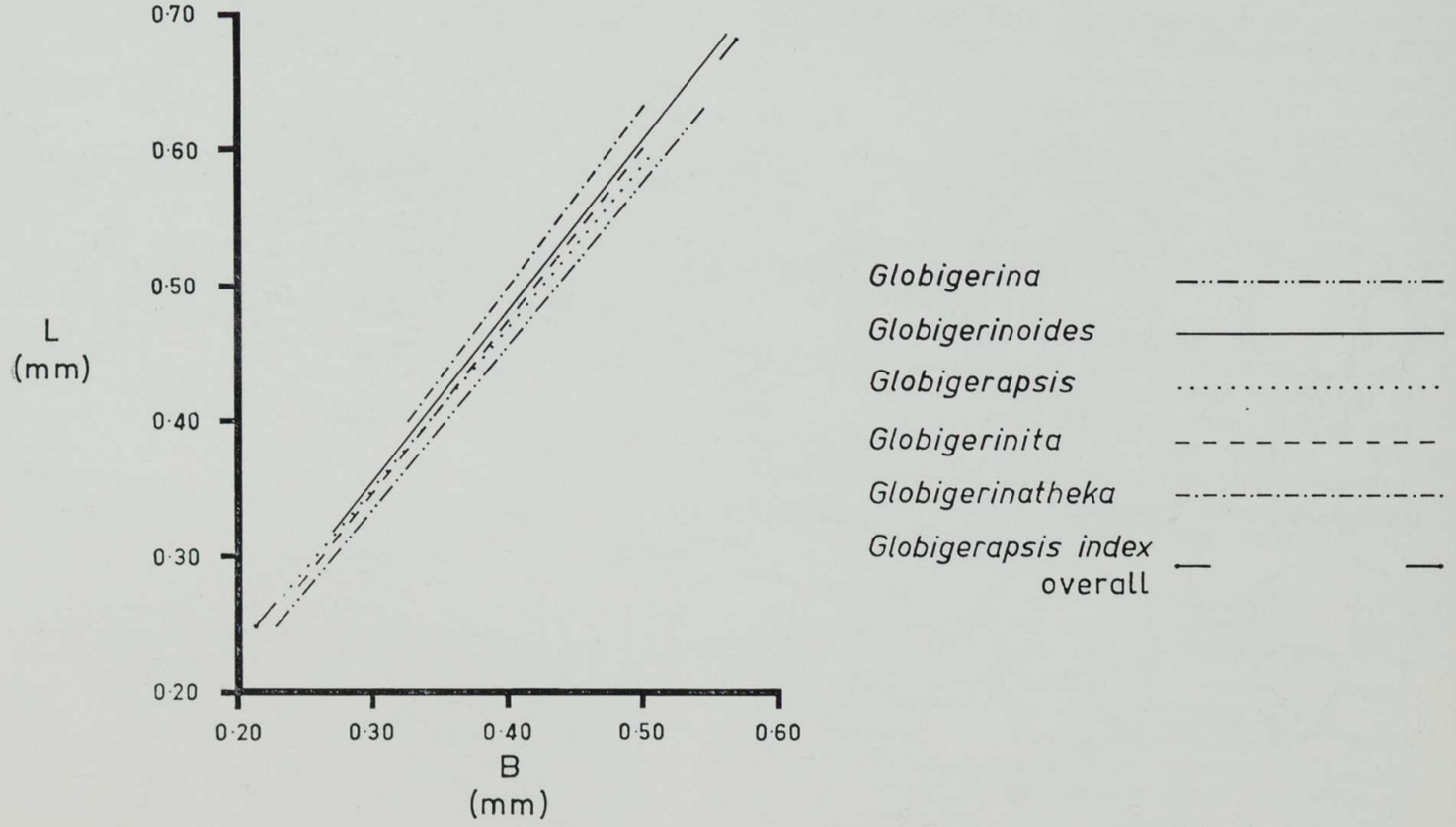


Figure 5.—Regression lines for various "generic" groups within *Globigerapsis index* (Finlay).

TABLE 1

Statistics calculated for the " generic " groups within Globigerapsis index (*Finlay*)

Statistic	*Globigerina*	*Globigerinoides*	*Globigerapsis*	*Globigerinita*	*Globigerinatheka*	Species Overall
N	271	54	63	42	6	436
Range of L	0.21–0.53mm	0.27–0.57mm	0.23–0.50mm	0.24–0.51mm	0.34–0.53mm	0.21–0.57mm
Range of B	0.18–0.45mm	0.24–0.47mm	0.18–0.43mm	0.19–0.42mm	0.26–0.41mm	0.18–0.47mm
$\overline{L}$	0.36mm	0.40mm	0.36mm	0.36mm	0.42mm	0.37mm
$\overline{B}$	0.31mm	0.33mm	0.31mm	0.30mm	0.34mm	0.31mm
S_L	0.06mm	0.063mm	0.068mm	0.055mm	0 090mm	0.063mm
S_B	0.05mm	0.050mm	0.057mm	0.044mm	0.067mm	0.051mm
a	0.843	0.790	0 845	0.801	0 742	0.820
b	—0.0004mm	+0.0109mm	—0.0015mm	+0.013mm	+0.0237mm	+0.0061mm
r	0.95	0.933	0.962	0.932	0.975	0.948
r_a	0.0001mm	0.0003mm	0.0002mm	0.0004mm	0 0006mm	0.0001mm
Equation of line	B = 0.843L — 0.0004	B = 0.79L+ 0.0109	B = 0.845L — 0.0015	B = 0.80L+ 0.013	B = 0.742L + 0.0237	B = 0.82L + 0.0061

TABLE 2

Results of significance tests on slope of lines. Figures presented are values of z_1 (*see text*)

	Globigerina	*Globigerinoides*	*Globigerapsis*	*Globigerinita*	*Globigerinatheka*	Species Overall
Globigerina		1.26	0.08	0.87	1.45	1.08
Globigerinoides			1.14	0.20	0.61	0.76
Globigerapsis				0.82	1.40	0.77
Globigerinita					0.73	0.41
Globigerinatheka						1.14

TABLE 3

Results of significance tests on position of lines with respect to L. Figures presented are values of z_2

	Globigerina	*Globigerinoides*	*Globigerapsis*	*Globigerinita*	*Globigerinatheka*	Species Overall
Globigerina		4.16	0.08	1.10	6.49	1.11
Globigerinoides			5.82	2.52	6 85	7.72
Globigerapsis				1.30	12.57	1.67
Globigerinita					6.61	0.32
Globigerinatheka						8.51

Taking the statistics shown in Table 3, those tests involving *"Globigerinatheka"* type individuals can probably be ignored as only six specimens were tested. Any other test values greater than 1.96 involve *"Globigerinoides"* type individuals. The discrepancy on the latter group can be explained conveniently, as it is often difficult to decide whether or not the ultimate chamber is, or is not, a little displaced from the normal growth spiral. When it is clearly displaced, the specimen is a *"Globigerapsis"* type; when it is not, it is a *"Globigerinoides"* type. There is a group in which it is hard to decide. When members of this group are included in *"Globigerinoides"*, the measured length/breadth ratio is altered.

With these provisos in mind, it is clear that these "generically different" groups show no significant difference in spiral growth habit, and may be expected to be closely related. However, they also have in common, wall structure, sutural characters etc., and differ only in characters relating to the ultimate chamber and its aperture(s) and bulla(e) i.e. they are similar in all characters generally accepted as being of specific importance. Thus it seems that these "generically different" groups are biologically conspecific.

The bulla

The bulla of *Globigerinita* and the modified ultimate chamber of *Globigerapsis* differ in wall structure as seen in thin section (see Table 4). The function of the bulla is debated. Hypotheses put forward for its use include:

(1) It is a reproductive feature (Hofker, 1959; Pokorny, 1963),

(2) It is a floating mechanism (Subbotina, 1953),

(3) It is a "weight increasing" mechanism (Bolli, Loeblich and Tappan, 1957),

(4) It is a floating and orienting mechanism.

TABLE 4

Measurements of wall characters of two specimens of Globigerapsis index *(Finlay)*

	Globigerinita type	*Glabigerapsis* type
Wall Thickness—		
(*a*) bulla	10u	
(*b*) modified ultimate chamber		14u
Wall thickness of preceding chamber	22u	16–18u
Distance between pores—		
(*a*) bulla	6u	
(*b*) modified ultimate chamber		8–10u
Distance between pores in preceding chamber	11u	10u
Diameter of pores—		
(*a*) bulla	2u	
(*b*) modified ultimate chamber		3–4u
Diameter of pores in preceding chamber	3–4u	3–4u

Parker (1962, p. 246) states that a bulla is found in young and adult specimens alike and this seems a better reason against a reproductive function than the observations advanced by Hofker (1959) for a reproductive use. Assuming that she distinguishes young from adult specimens on the basis of size, Parker's observation may be put another way, i.e. that bullae are found not only on large specimens but also on smaller specimens. This may mean that mature specimens, small or large, carry bullae, rather than young and adult. The observations given on *Globigerina ampliapertura* (herein, *q.v.)* suggest that only part of the population carries bullae and that that part may be microspheric. This would support the contention that it has some sort of reproductive function.

To be a floating mechanism, the bulla would probably have to entrap gas. This solution is as likely as some others. Another possibility is that it also served as an orienting mechanism. The pores which are finer and more numerous on the bulla than on previous chambers would give rise to finer, more numerous and probably shorter, pseudopods than the normal chamber. This has been figured in a specimen of *Globigerinoides sacculifer* (Brady), (Kükenthal and Krumbach, 1921, p. 81, fig. 64). This imbalance of pseudopod concentration plus a possible gas concentration may favour a particular orientation of the test. Study of living globigerinids is necessary to clear up the question.

The ultimate chamber

Forms with more than one aperture in the ultimate chamber were found to be of three types.

(a) The *"Globigerinoides"* type in which the ultimate chamber is part of the normal growth spiral and possesses a primary umbilical aperture markedly larger than any supplementary apertures.

(b) The *"Globigerapsis"* type in which the ultimate chamber, although not part of the normal growth spiral, is texturally the same as preceding chambers, sits over the umbilicus of the previously formed test and possesses more than one aperture of approximately equal size. The ultimate chamber is often hemispherical or rather flattened and reduced in size in contrast to the normal globular ultimate chamber. This *"Globigerapsis"* type ultimate chamber will be referred to throughout as a "modified ultimate chamber" to distinguish it from the bullae of the following types—the *"Globigerinita"* and *"Globigerinatheka"* types.

(c) The *"Globigerinita"* and *"Globigerinatheka"* types are characterised by the possession of bullae, the walls of which are texturally different from those of earlier chambers on the specimens on which the bullae are found. The walls are thinner, more finely perforate and the pores are closer together than in earlier chambers. The walls of the bullae and of the modified ultimate chamber of *Globigerapsis index* differ in thickness, pore size and pore density.

Figure 6 (facing page.)

No. I, II *Globanomalina micra* (Cole); I. U.W.A.G.D. 59502, X135. II. U.W.A.G.D. 59503, X70. Bullate specimen.

III, IV *Globigerina* cf *africana* (Blow and Banner); U.W.A.G.D. 59505, X50.

V-VIII *G. ampliapertura* form *ampliapertura* Bolli; V-VII U.W.A.G.D. 59506, X65. VIII Section of bullate specimen, U.W.A.G.D. 59536, X50.

IX-XI *G. ciperoensis* form *angustiumbilicata* Bolli; U.W.A.G.D. 59507, X70.

XII-XV *G. ciperoensis* form *basaapertura* n. form; Holotype, U.W.A.G.D. 59513; XII-XIV X70; XV. Enlarged view of apertural area, X135.

XVI, XVII *G.* cf *echinata* (Bolli); U.W.A.G.D. 59508, X70.

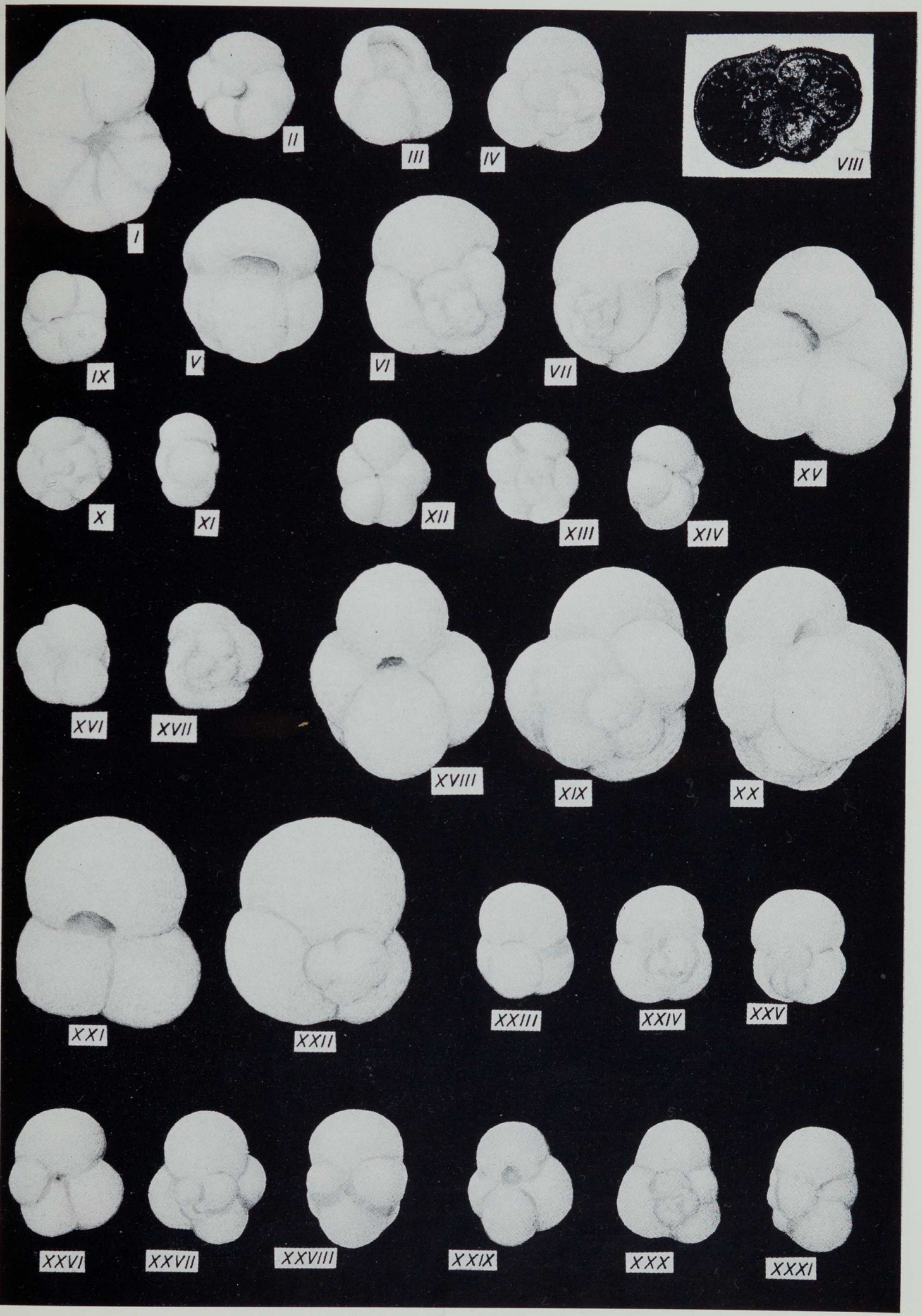
XVIII-XX *G. gortanii* form *praeturritilina* Blow and Banner; U.W.A.G.D. 59504, X120.

XXI, XXII *G. jenkinsi* n. sp., Holotype, U.W.A.G.D. 59525, X135.

XXIII-XXV *G. linaperta* form *linaperta* Finlay; U.W.A.G.D. 59509, X70.

XXVI-XXVIII *G. martini* (Blow and Banner), U.W.A.G.D. 59510, X65.

XXIX-XXXI *G. officinalis* subbotina, U.W.A.G.D. 59511, X65.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Conclusions

The statistical analysis presented here suggests fairly conclusively that all the specimens examined belong to a single population, and thus to a single species, even though some results of the z_2 test may be a little subjective. It also follows that they must all belong to the same genus.

It is proposed here that, ideally, genera must be defined in terms of (a) phylogeny, and (b) a set of morphological characters, and that species must depend on a population and not just on a single specimen. To date, the palaeontological habit seems to have depended on single specimens and a set of morphological characters.

Using the bases just proposed, *Globigerapsis* is here taken as a genus which developed in the Lower or Middle Eocene, probably from a *Globigerina* root stock, and which became extinct in the Upper Eocene, apparently without descendants. The characters of the ultimate chamber vary widely as indicated previously. It differs from *Globigerinoides* in that it belongs to a different lineage also derived from a *Globigerina* ancestral stock. Thus *Globigerapsis* is a valid genus and is here used to include that species defined by Finlay (1939B) as *Globigerinoides index*.

On the partly phyletic basis used here to define genera, such genera as *Catapsydrax, Tinophodella* and *Globigerinita* can only be used in the same sense as that in which *Globigerapsis* is here used, that is they must each belong to a different monophyletic group. *Tinophodella* and *Globigerinita* can probably be found in the one population and *Tinophodella* may well be a synonym of *Globigerinita* as has been suggested or implied several times already. *Globigerinita* should be reserved for nonhispid populations containing bullate forms as indicated by Parker (1962). These names cannot be used for individual specimens found in populations of species from a different lineage, and thus cannot be used for the specimens of *Globigerapsis* studied here.

Globigerinatheka, Inordinatosphaera, Globigerinoita and *Globigerinatella* are probably all only complex variants of populations belonging to species of previously defined genera and as such must be rejected.

Maximum diameter of figured specimens

(a) *Globigerina* type 0.41mm

(b) *Globigerinita* type 0.47mm

(c) *Globigerinatheka* type 0.55mm

(d) Section to show bulla structure 0.45mm.

Repository: (a) U.W.A.G.D.59532

(b) U.W.A.G.D.59533

(c) U.W.A.G.D.59534

(d) U.W.A.G.D.59535

Family GLOBOROTALIIDAE

Genus TURBOROTALIA Cushman and Bermudez, 1949

Turborotalia cf *centralis* (Cushman and Bermudez), 1937

Fig. 7, no. XLIX, L

cf *Globorotalia centralis* Cushman and Bermudez 1937, p. 26, pl. 2, figs. 62-65.

cf *Globorotalia (Turborotalia) centralis* Cushman and Bermudez; Cushman and Bermudez 1949, p. 42.

cf *Globorotalia centralis* Cushman and Bermudez; Bolli, Loeblich and Tappan, 1957, p. 41, pl. 10, figs. 4a-c.

cf *Turborotalia centralis* Cushman and Bermudez; Loeblich and Tappan 1964, p. C668, figs. 533, 6.

cf *Globorotalia centralis* Cushman and Bermudez; Jenkins 1965A, fig. 2.

Variation and Remarks

Eight specimens are questionably referred to this species. Maximum diameter varies from 0.20-0.42 mm with a mean value of 0.30 mm. Seven are sinistrally coiled.

The identification is very tentative as the diameters of the specimens in the present sample are very much smaller than is usual for *T. centralis*. Most recorded samples are quite large (0.4-0.7mm). The figures of the holotype (Cushman and Bermudez, 1937; Bolli, Loeblich and Tappan, 1957; Loeblich and Tappan, 1964) are of a specimen larger than, but otherwise extremely similar to the largest specimen found here and figured. The sample seems very different from figures of specimens other than holotype, for example that figured by Bolli (1957B, pl. 39, figs. 1-4).

On the basis of the rest of the planktonic foraminiferal fauna, the sediments are perhaps a little younger than those normally containing *T. centralis*. This also makes the identification a little questionable. Maximum diameter of figured specimen 0.42 mm.

Repository: U.W.A.G.D. 59537.

Turborotalia increbescens form *nana* (Bolli), 1957.

Fig. 7, no. LI, LII

Globorotalia opima nana Bolli 1957A, p. 118, pl. 28, figs. 3a-c.

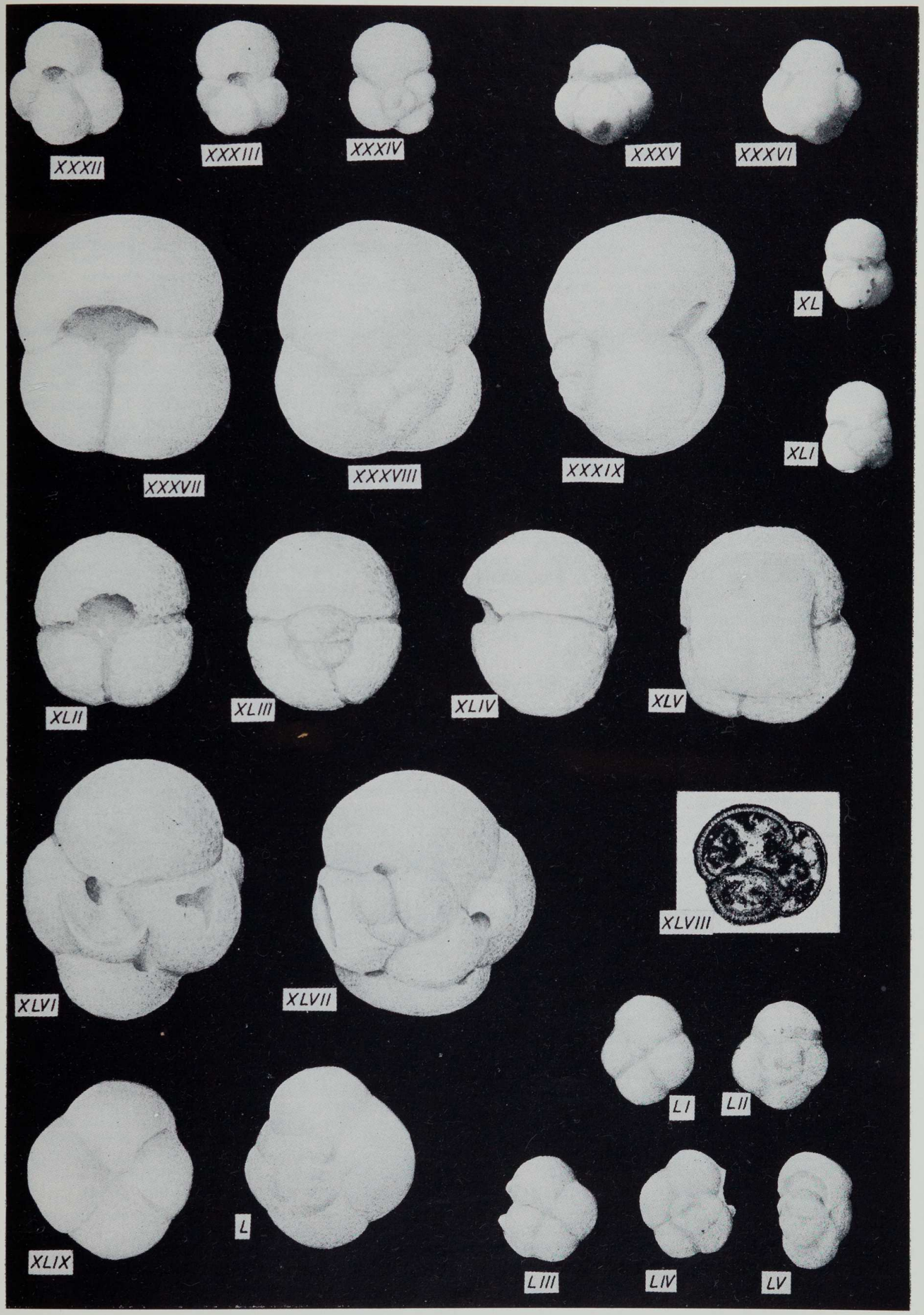
Globorotalia opima nana Bolli; Blow and Banner (*in* Eames *et al.*) 1962, pp. 119-120, pl. 13, figs. Q-S.

? *Globorotalia opima* Bolli; Wade 1964, pl. 1, fig. 23.

Globorotalia nana Bolli; Jenkins 1965A, fig. 2.

Figure 7 (facing page.)

No. XXXII	*Globigerina ouachitaensis* form *ouachitaensis* Howe and Wallace; U.W.A.G.D. 59512, X60.
XXXIII, XXXIV	*G. praebulloides* form *praebulloides* Blow; U.W.A.G.D. 59519, X70.
XXXV, XXXVI	*G. senilis* Bandy; U.W.A.G.D. 59522, X55.
XXXVII-XXXIX	*G. tripartita* form *tapuriensis* Blow and Banner; U.W.A.G.D. 59523, X65.
XL, XLI	*G. yeguaensis* cf form *yeguaensis* Weinzierl and Applin; U.W.A.G.D. 59524, X55.
XLII-XLVIII	*Globigerapsis index* (Finlay); XLII-XLIV *Globigerina* type; U.W.A.G.D. 59532, X65. XLV *Globigerinita* type; U.W.A.G.D. 59533, X65. XLVI, XLVII *Globigerinatheka* type; U.W.A.G.D. 59534. X75. XLVIII Section through bulla and two chambers showing thin bulla wall, U.W.A.G.D. 59535, X45.
XLIX, L	*Turborotalia* cf *centralis* (Cushman and Bermudez); U.W.A.G.D. 59537, X65.
LI, LII	*T. increbescens* form *nana* (Bolli); U.W.A.G.D. 59538, X70.
LIII-LV	*T. permicra* (Blow and Banner); U.W.A.G.D. 59539, X70.


XXXII
XXXIII
XXXIV
XXXV
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LV

Remarks

Of 37 specimens recovered, 35 are dextrally coiled. Maximum diameter range from 0.17 to 0.30 mm with an average value of 0.23 mm.

Although Blow and Banner (*in* Eames *et al.*, 1962, p. 118) compared and contrasted *T. increbescens* form *increbescens* with *T. centralis* Cushman and Bermudez, a better comparison seems to be with *T. increbescens* form *nana* (Bolli) (referred by them to *Globorotalia opima nana*). The only difference between the two forms is in the apertural characters. In this sample, similarities in size, granularity and perforation of the wall, rate of increase of chamber size etc., indicate that *T. opima nana* and *T. increbescens* (Bandy) are conspecific.

Blow and Banner noted that three 'subspecies', (the previously mentioned two, plus *T. i. opima*) are probably conspecific but did not give them the same specific name. The evolution of the species (*T. increbescens* and *T. opima*) as indicated by them—lineage A (p. 130-131)—is simplified if all forms are considered as one species.

The specific name *increbescens* has precedence over *opima* and the form name *increbescens* is added to distinguish the three forms of the species, i.e. *T. increbescens increbescens* Bandy, *T. increbescens opima* Bolli and *T. increbescens nana*. *T. opima* form *continuosa* Blow is separated as a species in its own right and becomes *T. continuosa*.

Maximum diameter of figured specimen 0.25 mm.

Repository: U.W.A.G.D. 59538.

Turborotalia permicra (Blow and Banner), 1962.

Fig. 7, no. LIII-LV

Globorotalia permicra Blow and Banner (*in* Eames *et al.*) 1962, p. 120, pl. 12, figs. N-P.

Remarks

This species is very similar to some figured specimens of *T. pseudobulloides* (Plummer). The only distinct morphological difference appears to exist in the apertural characters. Bolli (1957C, p. 73) stated that the aperture of *T. pseudobulloides* is a low arch whereas Blow and Banner (*in* Eames *et al.*, 1962, p. 120) stated that *T. permicra* has a high arch for an aperture. However this simple distinct difference is made less useful by Troelsen's (1957, p. 129) statement that the aperture of *T. pseudobulloides* is large, although his figures (Pl. 30, figs. 6-8) showed no significant size difference between the aperture of his specimens and those of Bolli (1957C, Pl. 17, figs. 19-21) and Loeblich and Tappan (1957, Pl. 40, figs. 3a-c; Pl. 41, figs. 1a-c; Pl. 42, figs. 3a-c; Pl. 43, figs. 3a-4c; Pl. 44, figs. 4a-6c; Pl. 45, figs. 1a-2c; Pl. 46, figs. 6 a-c), none of which shows the high arch possessed by *T. permicra*.

The maximum diameter of *T. pseudobulloides* ranges from 0.16 mm—0.50 mm (Bolli 1957; Troelsen 1957; and Loeblich and Tappan 1957) whereas that of the figured holotype of *T. permicra* is only 0.155 mm. There is probably some overlap but there may be a statistically significant difference in average values.

The most marked difference between the species is one of time range. *T. pseudobulloides* has an overall range of Lower and Middle Palaeocene while that of *T. permicra* seems to be upper Upper Eocene and at least Oligocene.

The rate of increase of chamber size is slightly less in the present sample than in the holotype.

Of 11 specimens in the sample, seven (64%) are sinistrally coiled. Average size is 0.23 mm with a size range of 0.17 to 0.27 mm—a value a little larger than that of the holotype.

Maximum diameter of figured specimen 0.25 mm.

Repository: U.W.A.G.D. 59539.

Correlation and age of the Nanarup Limestone Member

The nautiloids *Aturia clarkei* Teichert and *Teichertia prora* Glenister, Miller and Furnish (1956) suggest a Middle to Upper Eocene age for the Plantagenet Group, based on the faunas with which they are associated in northwest Western Australia.

If one accepts Bolli's (1957B) zonation of the Upper Eocene of Trinidad, the Nanarup planktonic fauna does not fit uniquely any one of his zones. However, if, following Bandy (1964), the *Globorotalia cerroazulensis* and *Globigerapsis semiinvolutus* Zones are combined, the Nanarup fauna can be correlated with the combined zone.

There are marked discrepancies in the time ranges credited by different authorities to the various species found at Nanarup. One only has to compare the time ranges listed by Bolli (1957B), Blow and Banner (*in* Eames *et al.*, 1962), Jenkins (1965A) etc., to be forced to the conclusion that the same species may have markedly different time ranges in different parts of the world.

It seems that the Upper Eocene can be recognised internationally as only one zone on the basis of planktonic foraminifera, and that this international zone can be subdivided into two or three local subzones. The Nanarup fauna can be correlated directly and convincingly so far only with zonation schemes in Australia, New Zealand, Solomon Islands and Tanzania. This fact may be a reflection of an Upper Eocene planktonic foraminiferal faunal province.

In Australia, the fauna correlates with Carter's (1958 A and B) Faunal Unit 2 on the basis of present *Globigerapsis index, Globanomalina micra, Globigerina linaperta* and absent *Hantkenina*.

Ludbrook and Lindsay (1967) have proposed a zonation scheme very similar to that put forward by Jenkins (1965A) for New Zealand. In Ludbrook and Lindsay's terms, the fauna correlates with the *Globigerina linaperta* Zone. In Jenkins' scheme, correlation is with the Upper Runangan (upper part of *Globigerina linaperta* Zone and lower part of *G. brevis* Zone.

In Tanzania, Blow and Banner (*in* Eames *et al.*, 1962) recognised three zones in the Upper Eocene. The Nanarup fauna correlates well with the *Globigerina turritilina* (=*gortanii*) *turriti-*

lina Zone which is the uppermost of the three. Common species include *Globanomalina micra*, *Globigerina ampliapertura* form *ampliapertura*, *G. linaperta* form *linaperta*, *G. gortanii* form *turritilina*, *G. ciperoensis* form *angustiumbilicata* etc. *Hantkenina* is absent from faunas in both areas.

McTavish (1966) gave a zonation scheme for the British Solomon Islands. The Nanarup fauna correlates with his *Globigerina ampliapertura/G. linaperta* Fauna.

By virtue of its position in the southern hemisphere zonation schemes, we know that the Nanarup fauna is very high in the Upper Eocene. In terms of the European subdivisions of the Upper Eocene, it probably belongs to the Wemmelian, Priabonian or Lower Ludian [in the sense in which those terms are used by Thenius (*in* Lotz, 1959)]. Following Gignoux (1955), the fauna is Ludian (= Wemmelian = Upper Priabonian).

Conditions of formation

If Loeblich and Tappan (1964, p. C116 *et seq.*) are correct in proposing that dominant dextral coiling in planktonic species is a record of warm water, the Nanarup fauna is a warm water one, as the fauna is about 95% dextrally coiled overall, with *Globigerina ampliapertura* form *ampliapertura* the only noteworthy exception. The diversity of the planktonic fauna also supports this contention. Many aspects of the benthonic fauna also support a warm water origin and these will be recorded elsewhere.

The planktonic element constitutes 10% of the foraminiferal fauna. This is consistent with a depth of formation of about 120 ± 60 feet (Phleger, 1960, p. 258, 259). Some aspects of the benthonic fauna suggest a little deeper formation but this also will be discussed elsewhere.

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